PTO 07-1299

CY=JA DATE=19920825 KIND=A
PN=04-236426

SEMICONDUCTOR MANUFACTURING DEVICE
[Handoutai seizou souchi]

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UNITED STATES PATENT AND TRADEMARK OFFICE
Washington, D.C. December 2006

Translated by: FLS, Inc.

PUBLICATION COUNTRY	(19):	JP
DOCUMENT NUMBER	(11):	040236426
DOCUMENT KIND	(12):	A [PUBLISHED UNEXAMINED APPLICATION]
PUBLICATION DATE	(43):	19920825
APPLICATION NUMBER	(21):	03019337
APPLICATION DATE	(22):	19910118
INTERNATIONAL CLASSIFICATION	(51):	H 01 L 21/302; H 05 H 1/18
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APPLICANT	(71):	MITSUBISHI ELECTRIC CORPORATION
TITLE	(54):	SEMICONDUCTOR MANUFACTURING DEVICE
FOREIGN TITLE	(54A):	HANDOUTAI SEIZOU SOUCHI

[Claims] /2*

[Claim 1] A semiconductor manufacturing device for etching an objective film by using a microwave ECR etcher

characterized in that it is equipped with a means for measuring the level of the microwaves reflected on the ECR plane and in that it detects the etching endpoint of the objective film based on the above-mentioned level of the output of the microwaves reflected on the ECR plane, which depends on the type of the objective film.

[Claim 2] A semiconductor manufacturing device according to Claim 1

characterized in that it is further equipped with a means for measuring the level of microwaves input to the microwave ECR etcher.

[Detailed Description of the Invention]

[0001] [Field of the Invention]

This invention relates to a semiconductor manufacturing device, specifically to a semiconductor manufacturing device capable of accurately measuring the endpoint of etching when an objective film is etched by using a microwave ECR etcher.

[0002] [Related Art]

Figure 9 is a structural drawing that schematically shows the device structure of a microwave ECR etcher. In Fig. 9, reference numeral [1] denotes etching gas, [2] denotes a gas inlet tube, [3] denotes a quartz bell jar, [4] denotes a treatment chamber, [5] denotes a microwave oscillator, [6] denotes microwaves, [7] denotes a microwave guide, [8] denotes a coil for generating an electromagnetic field, [9] denotes an

* Number in the margin indicates pagination in the foreign text.

ECR plane, [10] denotes plasma, [11] denotes a wafer, [12] denotes a reaction product including an element of the film to be etched or the element of the etching gas, [13] denotes an optical fiber, [14] denotes a filter, and [15] denotes a photomultiplier.

[0003] As shown in Fig. 9, the etching gas [1] is guided via the gas inlet tube [2] to the treatment chamber enclosed by the quartz bell jar [3]. The pressure inside the treatment chamber [4] is preset to a desired pressure. Next, microwaves [6] oscillated by the microwave oscillator [5] are guided via the microwave guide [7] to the treatment chamber [4] enclosed by the quartz bell jar [3], and the ECR plane [9] is generated at an appropriate height inside the treatment chamber [4] due to the interaction with a magnetic field which was generated in advance by the coil [8] for magnetic field generation. The dissociation probability of the etching gas inside the treatment chamber [4] peaks near the ECR plane [9], and the generation of the plasma [10] occurs. Consequently, etching advances on the surface of the wafer [11] placed inside the treatment chamber [4]. As the etching advances, the reaction product [12] comprising elements from the etched film and elements from the etching gas becomes attached to and accumulated on the inner wall of the quartz bell jar [3] over time.

[0004] According to related art, the endpoint of the above-described etching is determined by attaching the optical fiber [13] to an appropriate location of the microwave guide [7], incorporating light emission near the surface of the wafer by using the optical fiber, selecting only the light having a wavelength with which the advancement of etching can be

monitored the best by using the filter [14], photoelectrically converting the light by using the photomultiplier [15], and performing various calculations by using the voltage value.

[0005] Figure 10 is graphs for explaining a technique often utilized in the past to detect the endpoint of etching. In the following, a concrete example of the etching evaluation technique will be described. Figure 10 illustrates the light emission intensity of silica chloride ($SiCl^*$) near the wafer surface when chloride (Cl_2) and oxygen (O_2) are utilized as etching gases with their flow quantities set to 36 SCCM and 4 SCCM, respectively, when the etching pressure is set to 0.005 Torr, when the wafer temperature is set to -10°C, when 3500Å-thick polysilicon is used as the film to be etched, and the wavelength transmittable by the filter is set to 220nm. Moreover, the horizontal axis indicates the etch time, and the vertical axis indicates the light-emission voltage detected after photoelectric conversion has been carried out by the photomultiplier [15].

[0006] Silica chloride ($SiCl^*$) is a reaction product generated by the reaction between the chloride (Cl2) contained in the etching gas and polysilicon. When this silica chloride ($SiCl$) is in an active state ($SiCl^*$), 220nm-wavelength light is emitted. Therefore, Fig. 10 (a) indicates that etching is advancing in the range in which the voltage is high and that the etching of the polysilicon is nearing the endpoint in the range in which the voltage rapidly drops, which is around 50 seconds since the start of etching.

[0007] According to a calculation method often used to detect the

endpoint of etching, the voltage graph of Fig. 10(a) is subjected to secondary differentiation to achieve a secondary differential waveform such as that illustrated in Fig. 10(b). An appropriate value corresponding to the point at which the downward curve shifts to the upward curve as in Fig. 10(b), which in the case of Fig. 10(b) is the point at which the line crosses -0.5 for the second time (point A in the figure), is detected as the endpoint of etching.

[0008] However, since the reaction product [12] becomes deposited on the inner wall of the quartz bell jar over time in the above-described method, the intensity of light entering the photomultiplier [15] decreases over time. As a result, the voltage values of the waveforms decrease gradually as indicated in Fig. 11, (a) and (b), and the absolute values of the secondary differential waveforms also become smaller. Consequently, the secondary differential waveforms of the fifth wafers and beyond do not cross -0.5 when the downward curve shifts to the upward curve as in Figure 11(b), preventing accurate detection of the endpoints of etching. For this reason, some wafers [11] become overetched, and the device reliability is significantly lowered as a result.

[0009] Moreover, as shown in Fig. 12 which is a graph illustrating the light-emission voltage output from the photomultiplier [15], if an irregular voltage change occurs in the graph because of fluctuations in the light emission which occurs during a nonequilibrium state of plasma before the end of etching, and if the secondary difference at that point exceeds -0.5 (point B in the figure), this point becomes incorrectly detected as the endpoint of etching. This ends the etching prematurely,

and the polysilicon film will have non-etched areas left on it.

[0010] [Problems that the Invention is to Solve]

According to the related art, the intensity of the emitted light entering the photomultiplier becomes lower over time or the emitted /3
light becomes fluctuated by plasma in a nonequilibrium state as mentioned earlier, and the endpoint of etching becomes incorrectly detected as a result. This leads to a disadvantage of lowered device reliability.

[0011] This invention was devised in order to overcome the above disadvantage, and its aim is to provide a semiconductor manufacturing device capable of detecting the endpoints of etching stably for a long time regardless of the amount of the reaction products attached to the bell jar and also capable of preventing incorrect endpoints of etching from being detected, which would occur as a result of the emitted light being fluctuated by plasma in a nonequilibrium state.

[0012] [Means for Solving the Problems]

A semiconductor manufacturing device according to this invention detects endpoints of etching by monitoring the output intensity of microwaves during etching by using the fact that the output intensity of microwaves reflected on the ECR plane depends on the type of the film being etched.

[0013] [Operation of the Invention]

In a semiconductor manufacturing device of the invention, the output of microwaves which were reflected on the ECR plane is monitored during etching, thereby stably detecting the endpoints of etching for a long time regardless of the amount of reaction products attached to the bell

jar. Moreover, it does not detect endpoints incorrectly during the middle of etching, even if the light intensity is fluctuated by unstable plasma.

[0014] [Embodiments of the Invention]

Figure 1 is a model drawing of the semiconductor manufacturing device of one embodiment of the invention. Figures 2 through 8 are drawings for explaining the embodiment of the invention.

[0015] In Fig. 1, reference numeral [1] denotes etching gas, [2] denotes a gas inlet tube, [3] denotes a quartz bell jar, [4] denotes a treatment chamber, [5] denotes a microwave oscillator, [6] denotes microwaves, [7] denotes a microwave guide, [8] denotes a coil for generating an electromagnetic field, [9] denotes an ECR plane, [10] denotes plasma, [11] denotes a wafer, [12] denotes a reaction product including the components of the film to be etched or the components of the etching gas, [16] denotes a gauge for measuring the power of the microwaves input to the microwave guide, and [17] is a gauge for measuring the output power of the microwaves reflected on the ECR plane.

[0016] As illustrated in Fig. 1, the etching gas [1] is guided via the gas inlet tube [2] to the treatment chamber enclosed by the quartz bell jar [3]. The pressure inside the treatment chamber [4] is preset to a desired pressure. Next, microwaves [6] oscillated by the microwave oscillator [5] are guided via the microwave guide [7] to the treatment chamber [4] enclosed by the quartz bell jar [3], and the ECR plane [9] is generated at an appropriate height inside the treatment chamber [4] due to the interaction with a magnetic field which was generated in advance by the coil [8] for magnetic field generation. The dissociation probability

of the etching gas inside the treatment chamber [4] peaks near the ECR plane [9], and the generation of the plasma [10] occurs. Consequently, etching advances on the surface of the wafer [11] placed inside the treatment chamber [4]. As the etching advances, the reaction products [12] comprising elements from the etched film and elements from the etching gas become attached to and accumulated on the inner wall of the quartz bell jar [3] over time, and they accumulate more and more as more etching is carried out.

[0017] Furthermore, the microwave input power gauge [16] and the microwave output power gauge [17] are attached to the microwave guide [7] in areas near the microwave oscillator [5]. Moreover, the microwave input power gauge [16] measures the power of the microwaves [6] that entered the treatment chamber [4] after being oscillated from the microwave oscillator [5], and the microwave output power gauge [17] measures the power of the microwaves [6] reflected by the ECR plane [9].

[0018] Figure 2, (a), (b), and (c), are graphs indicating the correlation among the etching time, incident microwave power, and reflected microwave power observed when a polysilicon film, an oxide film, and a tungsten silicide film are etched by using a microwave ECR etcher having the structure of Fig. 1.

[0019] For the etching conditions, chloride ($Cl2$) and oxygen ($O2$) were used as etching gases at the flow rates of 36 SCCM and 4 SCCM, respectively; the etching pressure was set to 0.005 Torr, the wafer temperature was set to -10°C, and the incident microwave power was set to be 440W. As for the etching time, each of the films was etched for

30 seconds. As is clear from Figure 2(a), (b), and (c), the incident microwave powers of all of the films indicated a constant value (440W) in about 1 - 2 seconds after the start of etching and thereafter remained stable until 30 seconds after the start of etching.

[0020] However, according to Fig. 2(a), (b), and (c), the reflected microwave powers were 80W, 40W, and 60W for the polysilicon film, oxide film, and tungsten silicide film, respectively. Thus, they were different depending on the types of the films and remained constant until the end of etching. This is because the effective input power changes due to the plasma attempting to maintain equilibrium when the impedance is altered by the difference between the film types.

[0021] Figure 3(a), (b), and (c) are graphs illustrating the correlations among the incident microwave power, reflected microwave power, and etching time of each of a polysilicon film, oxide film, and tungsten silicide film observed when they were etched under the same etching conditions as those used in Fig. 2(a), (b), and (c), except for changing the etching pressure from 0.001 Torr to 0.005 torr to 0.010 Torr to 0.015 Torr.

[0022] According to Figs. 3(a), (b), and (c), the incident microwave power remained constant at 440W despite the changes in the etching pressure, but the reflected microwave power corresponding to each of the films was dependent on the pressure. Moreover, regardless of the pressure conditions, the values of the reflected microwave power were, with few exceptions, different among the polysilicon film, oxide film, and tungsten silicide film under the same pressure.

[0023] Figures 4(a), (b), and (c) are graphs illustrating the correlations among the incident microwave power, reflected microwave power, and etching time of each of a polysilicon film, oxide film, and tungsten silicide film observed when they were etched under the same etching conditions as those used in Fig. 2(a), (b), and (c), except for making the total flow rate of the etching gases constant and for varying the mixture ratio between the chloride and oxygen. /4

[0024] According to Figs. 4(a), (b), and (c), it is clear that, in the same manner as in Figs. 2(a), (b), and (c) and Figs. 3(a), (b), and (c), the reflected microwave power was different for each type of film even if the chloride/oxygen mixture ratio remained the same, except for the case in which the reflected powers of the polysilicon film and the tungsten silicide film became equal at the chloride/oxygen mixture ratio of 4 : 1 (32 CCM : 8 SCCM).

[0025] As mentioned earlier, according to Figs. 2(a), (b), and (c), Figs. 3(a), (b), and (c), and Figs. 4(a), (b), and (c), it is clear that, with few exceptions, the level of reflected microwave power depended greatly on the type of film being etched when the incident microwave power was kept constant.

[0026] Next, as shown in Fig. 5, a 1000Å-thick thermally-oxidized film [20] was disposed on bare silicon [21], and a polysilicon film [19] was deposited on it in the thickness of 3500Å. Moreover, a wafer provided with a resist pattern [18] was etched for 60 seconds under the same conditions as those of Figs. 2(a), (b), and (c). Figure 6 indicates the etching-time dependencies of the incident microwave power and reflected

microwave power observed at that time.

[0027] Based on Fig. 6, the incident microwave power is 440W and remains constant during the 60 seconds of etching. As for the reflected microwave power, it remains at 80W until 45 seconds have passed, then gradually changes to 40W between the 45th and 50th seconds, and thereafter becomes constant at 40W.

[0028] Figures 7(a), (b), (c), and (d) illustrate the surface conditions of a wafer observed after 40 seconds, 45 seconds, 50 seconds, and 55 seconds corresponding to Fig. 6. According to Fig. 7, the polysilicon [19] still remained on the entire wafer surface after 40 seconds, the oxide film [20] was partially exposed after 45 seconds, and all of the polysilicon had been etched away except in the space below the resist [18] after 50 seconds and 55 seconds.

[0029] Accordingly, the endpoint of etching can be detected by monitoring the reflected microwave output during etching and by appropriately calculating the waveform indicating changes in the reflected microwave output.

[0030] Figure 8(a) is a graph indicating the chronological changes in the incident microwave power and reflected microwave power that occurred in each of 25 wafers, the film structure of which is shown in Fig. 5, when they were etched under the same etching conditions as those used in Figs. 2(a), (b), and (c), and Fig. 8 (b) is a graph of the light-emission voltages of the active silica chloride ($SiCl^*$) measured near the surfaces of wafers similar to those above by using the conventional technique described by using Figs. 9 through 12.

[0031] Figure 8(b) indicates that, as it was described with reference to Fig. 11, the level of the light-emission voltage decreases as the etching process keeps being repeated. As opposed to this, Fig. 8 (a) indicates that the waveform of the reflected microwave power does not change even when the etching process is repeated.

[0032] Moreover, about 1 - 5 seconds after the start of etching is a period in which plasma transitions from nonequilibrium to equilibrium, and depending on the type of the film being etched, the fluctuations in the intensity of the emitted light may become substantial. However, such fluctuations are totally absent in the waveform of the reflected microwave power as shown in Fig. 8(a).

[0033] According to this embodiment, the endpoint of etching is detected by monitoring the reflected output of microwaves during etching. Therefore, the endpoint of etching can be detected stably over time even if etching is carried out continuously, and the device can be prevented from being unreliable because of overetching.

[0034] Moreover, it is possible to prevent incorrect detection of an etching endpoint, which would occur when the intensity of the emitted light fluctuates as a result of the plasma being unstable, and it is also possible to prevent the device reliability from being lowered by the polysilicon that remained after etching.

[0035] In addition, a situation in which the level of the microwave input power was kept constant was explained in the above embodiment, but if the level fluctuated for some reason, the fluctuation can be immediately detected by the microwave input power gauge [16]. Therefore, etching

endpoints can be detected accurately at all times based on the correlation between the incident power and reflected power.

[0036] [Effects of the Invention]

As described in the above, the present invention enables the detection of etching endpoint of a film being etched by using the microwave power reflected on the ECR plane, and is therefore not affected by the contamination level of the quartz bell jar or by the plasma in a nonequilibrium state. As a result, there are advantages in that etching endpoints can be detected stably and in that the device reliability can be improved.

[Brief Description of the Drawings]

[Figure 1] A model drawing of the semiconductor manufacturing device of one embodiment of the invention.

[Figure 2] Graphs indicating the etching-time dependencies of incident microwave powers and reflected microwave powers observed when three different types of films were etched by using the semiconductor manufacturing device of Fig. 1.

[Figure 3] Graphs indicating the etching-time dependencies of incident microwave powers and reflected microwave powers observed when the etching pressures were altered in the conditions of Fig. 2.

[Figure 4] Graphs indicating the etching-time dependencies of incident microwave powers and reflected microwave powers observed when the etching-gas mixture ratios were altered in the conditions of Fig. 2.

[Figure 5] A drawing showing an example of a film to be etched by

using the semiconductor manufacturing device of the embodiment of the invention.

[Figure 6] Graphs indicating the etching-time dependencies of incident microwave powers and reflected microwave powers observed when the objective film shown in Fig. 5 was etched.

[Figure 7] Drawings showing the chronological changes in the object film shown in Fig. 5 that occurred during etching.

[Figure 8] A graph indicating the etching-time dependencies of /5 the incident microwave power and reflected microwave power of each of 25 wafers, each of which was the same as the objective film in Fig. 5, observed during etching, and a graph indicating the etching-time dependencies of the light-emission voltages detected near the wafers.

[Figure 9] A drawing showing a conventional microwave ECR etcher.

[Figure 10] A drawing for explaining the conventional method for detecting an etching endpoint.

[Figure 11] A drawing for explaining part of the conventional problems.

[Figure 12] A drawing for explaining part of the conventional problems.

[Explanation of Reference Numerals]

[1] = etching gas

[2] = gas inlet tube

[3] = quartz bell jar

[4] = treatment chamber

[5] = microwave oscillator

[6] = microwaves

[7] = microwave guide

[8] = coil for generating an electromagnetic field

[9] = ECR plane

[10] = plasma

[11] = wafer

[12] = reaction product

[13] = optical fiber

[14] = filter

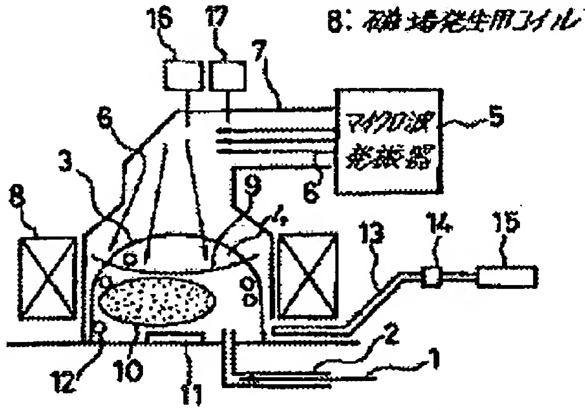
[15] = photomultiplier

[16] = incident microwave power gauge

[17] = reflected microwave power gauge

[Figure 1]

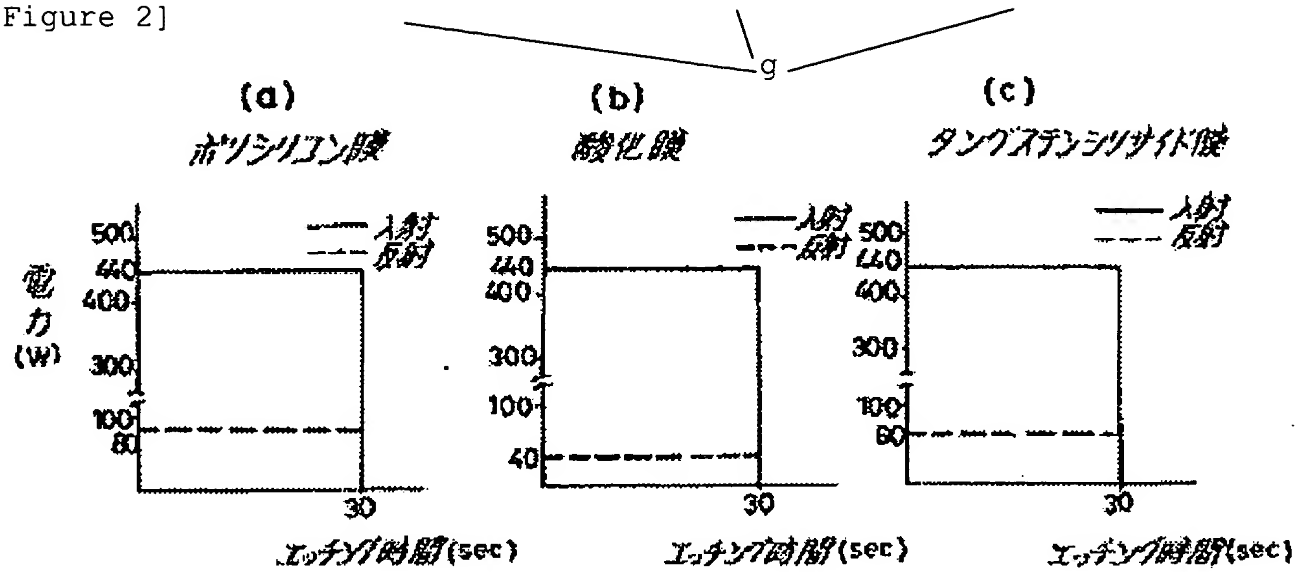
1: エッチングガス
2: ガス導入管
3: 石英ベルジャー
4: 処理室
6: マイクロ波
7: マイクロ波導波管
8: 磁場発生用コイル



9: ECR面
10: プラズマ
11: ウェハ
12: 反応性生成物
13: 光ファイバ
14: フィルタ
15: フォトマル
16: マイクロ波入射電力計測器
17: マイクロ波反射電力計測器

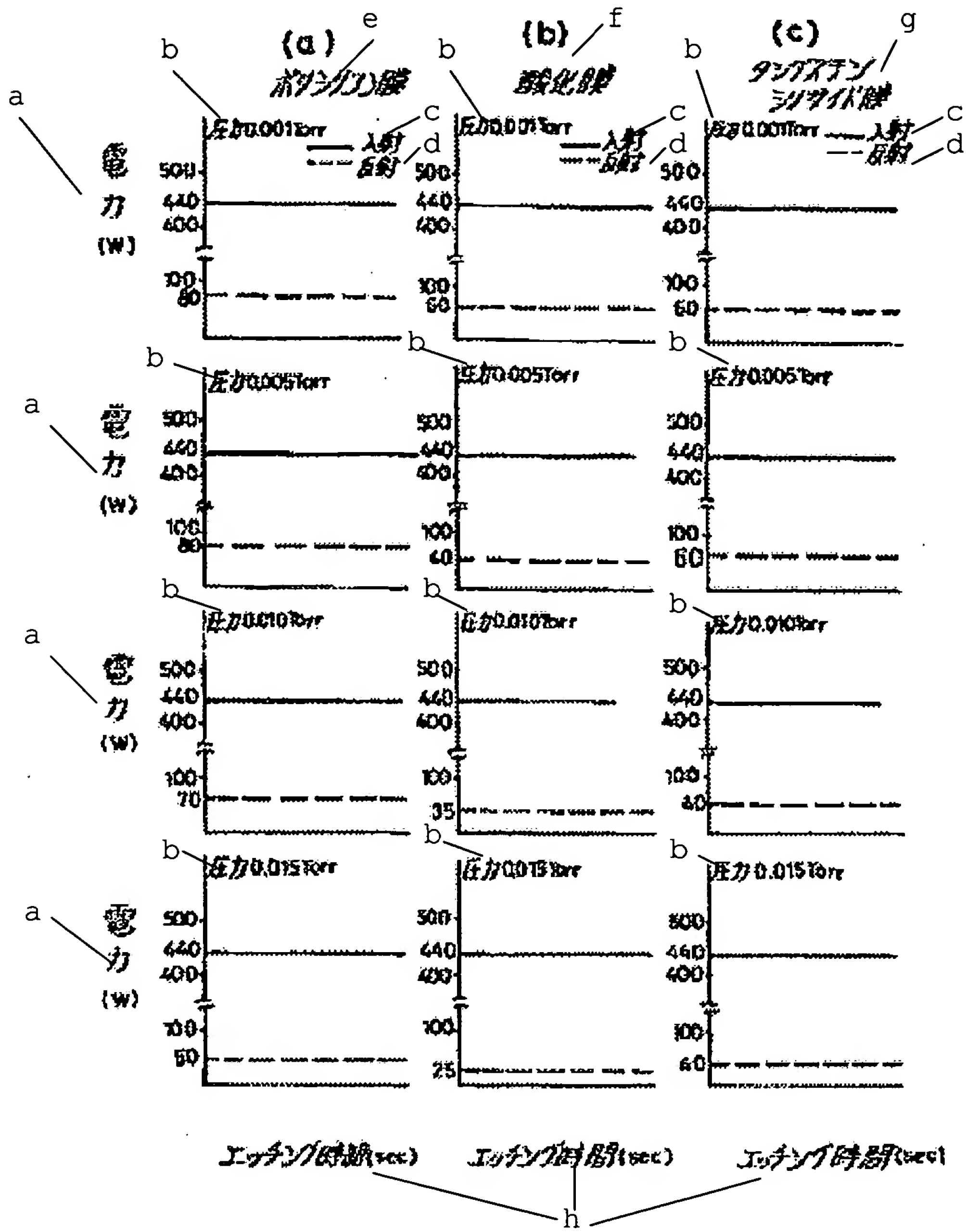
Key: 1)etching gas; 2)gas inlet tube; 3)quartz bell jar; 4)treatment chamber; 5)microwave oscillator; 6)microwaves; 7)microwave guide; 8)coil for generating an electromagnetic field; 9)ECR plane; 10)plasma; 11)wafer; 12)reaction product; 13)optical fiber; 14)filter; 15)photomultiplier; 16)incident microwave power gauge; 17)reflected microwave power gauge.

[Figure 2]



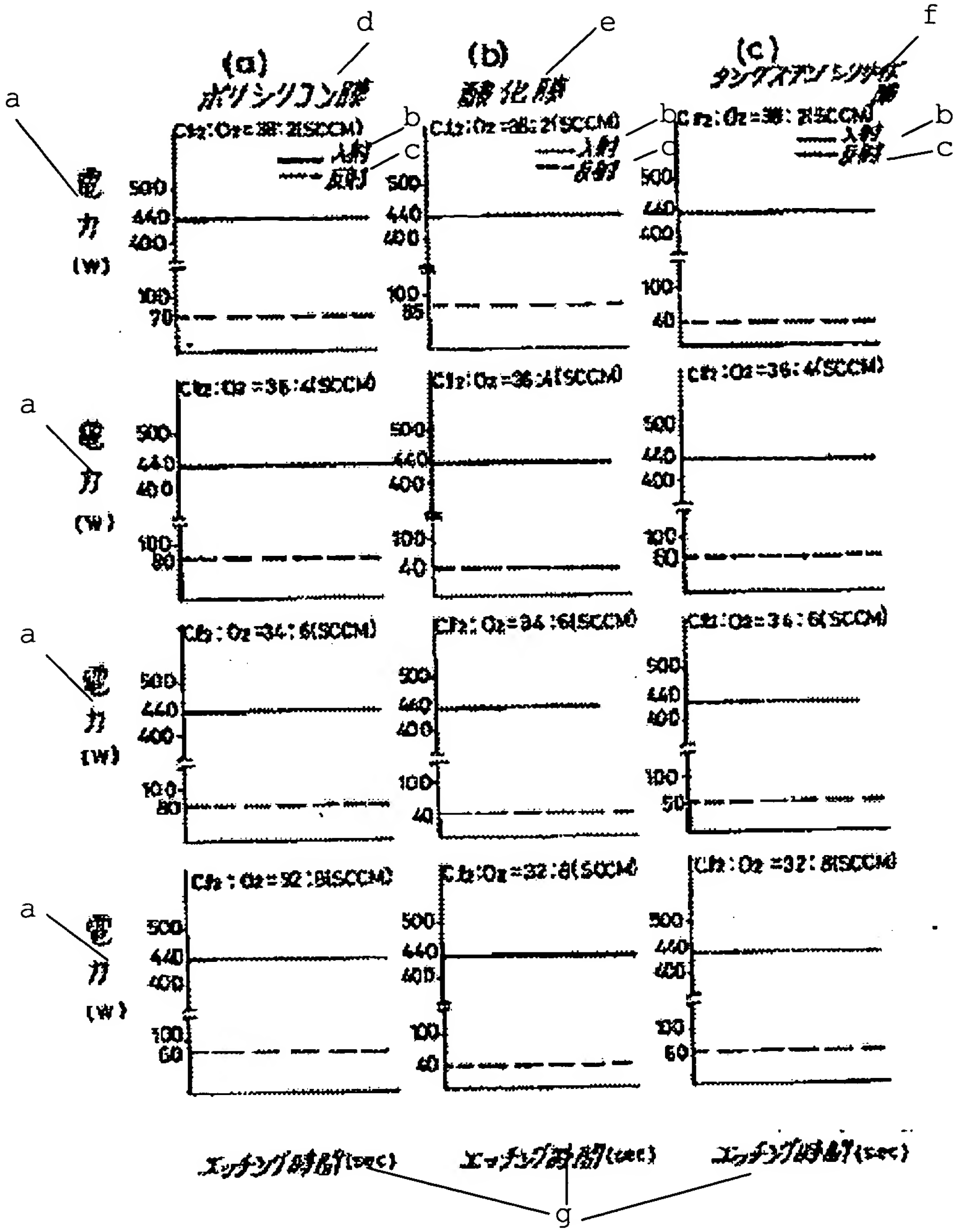
Key: a) Power (W); b) polysilicon film; c) incident; d) reflected; e) oxidized film; f) tungsten silicide film; g) Etching Time (sec).

[Figure 3]



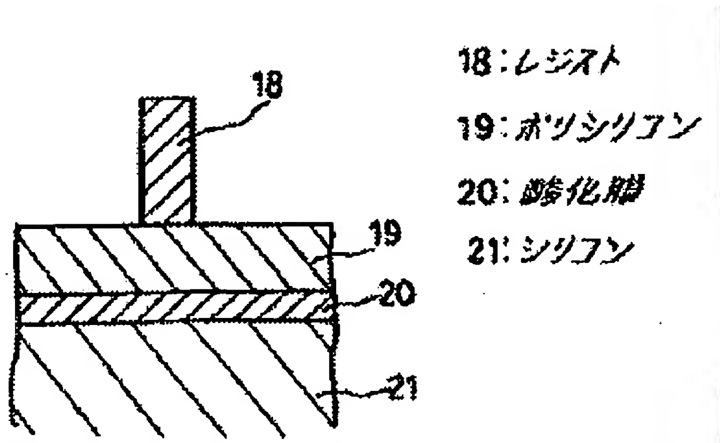
Key: a)Power (W); b)pressure; c)incident; d)reflected; e)polysilicon film; f)oxidized film; g)tungsten silicide film; h)Etching Time (sec).

[Figure 4]



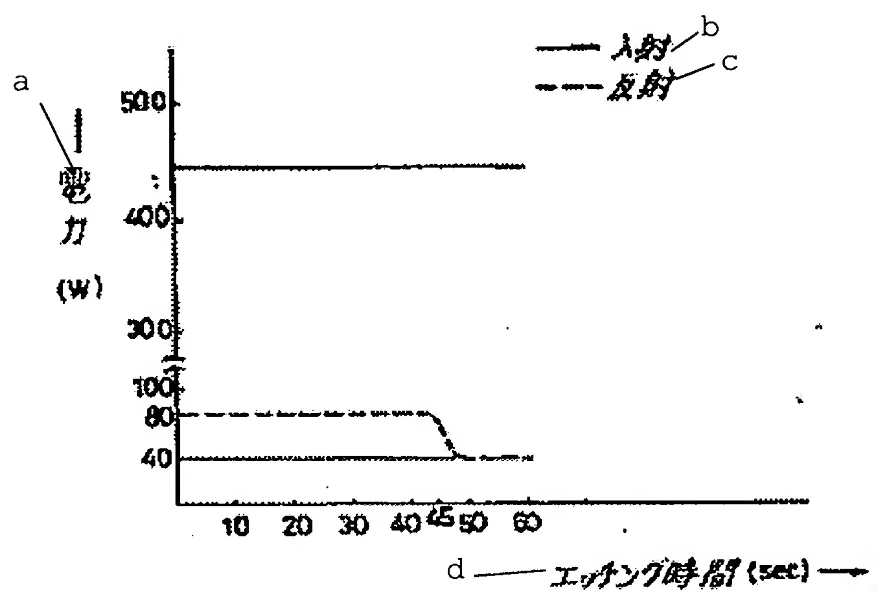
Key: a) Power (W); b) incident; c) reflected; d) polysilicon film; e) oxidized film; f) tungsten silicide film; g) Etching Time (sec).

[Figure 5]



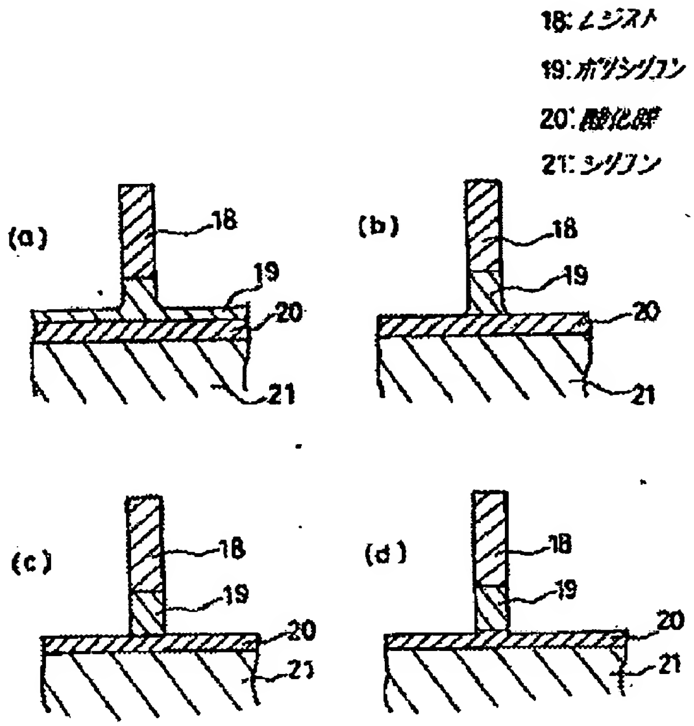
Key: 18)resist; 19)polysilicon; 20)oxidized film; 21)silicon.

[Figure 6]



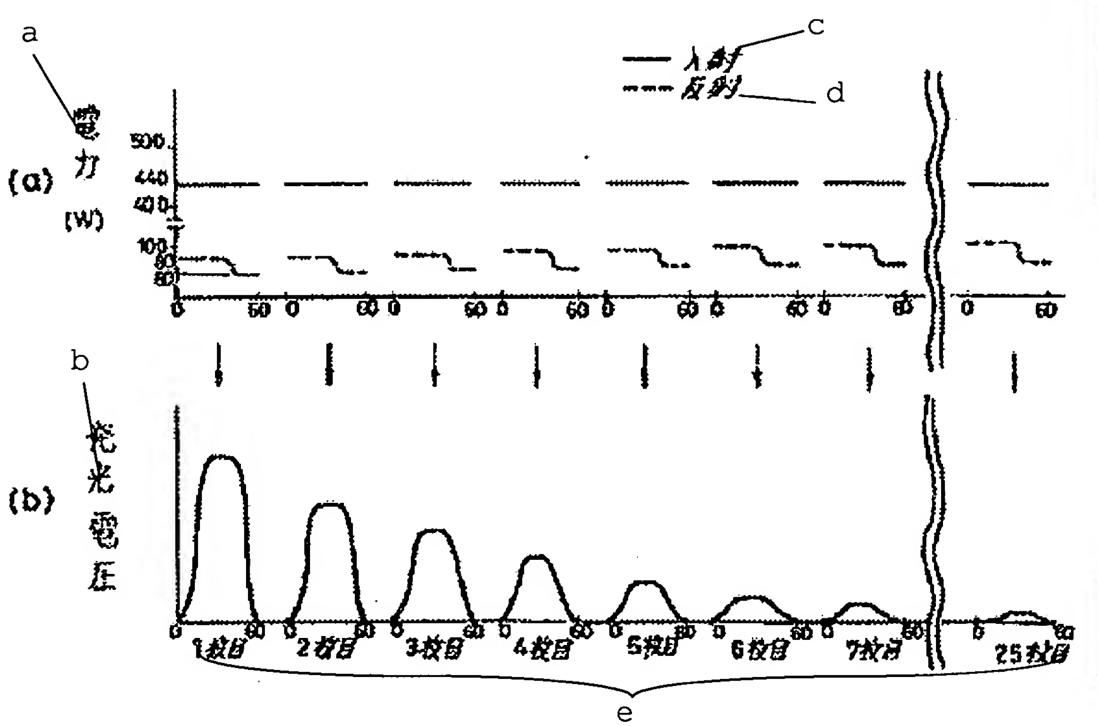
Key: a)Power (W); b)incident; c)reflected; d)Etching Time (sec).

[Figure 7]



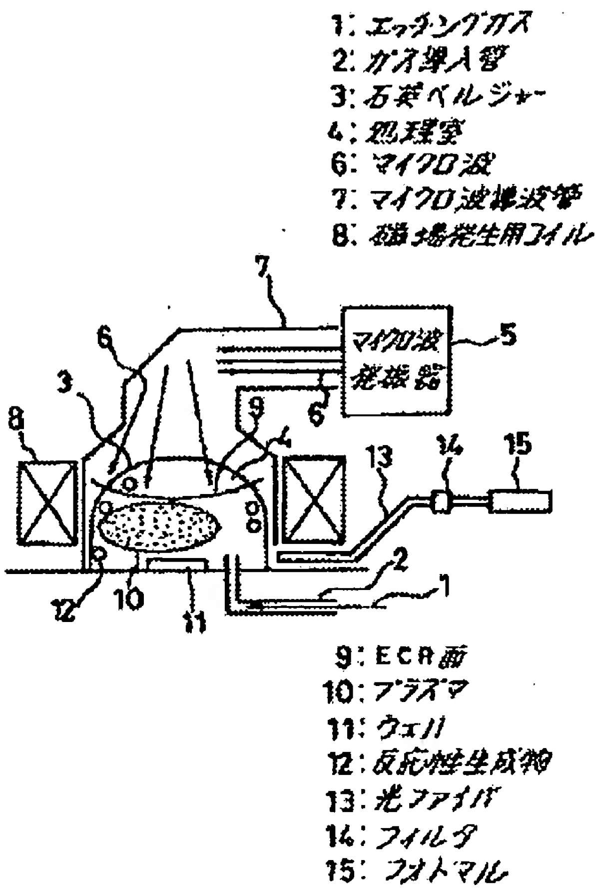
Key: 18) resist; 19) polysilicon; 20) oxidized film; 21) silicon.

[Figure 8]



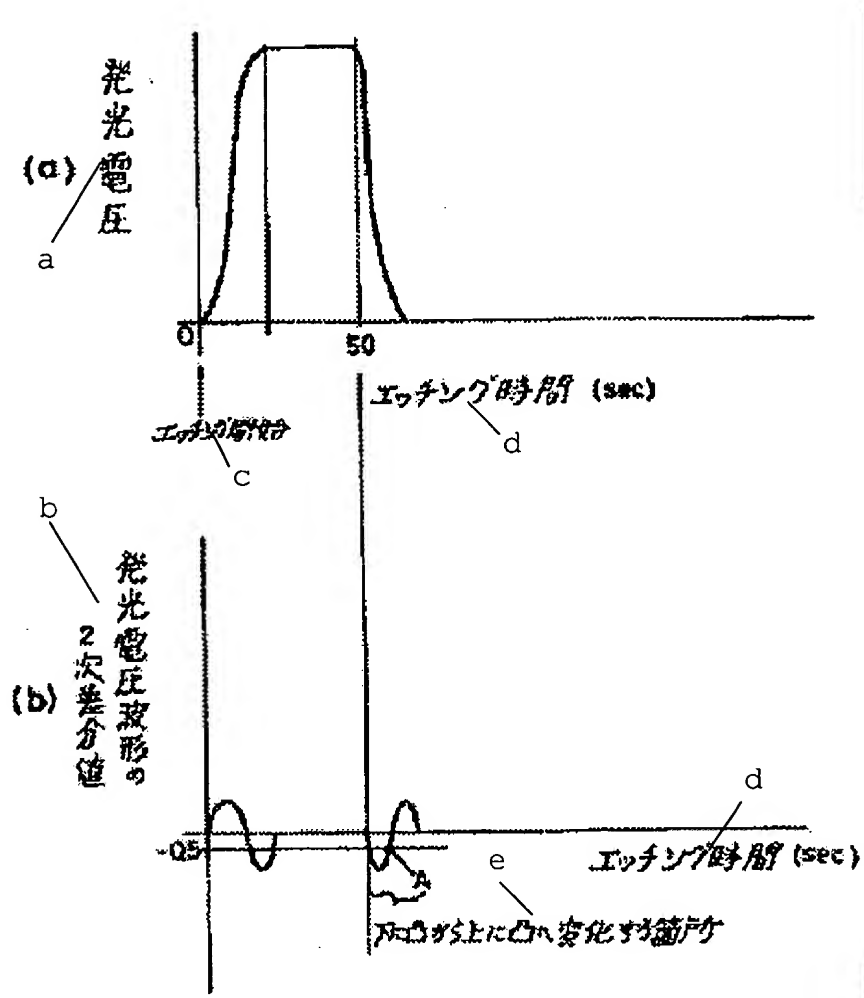
Key: a) Power (W); b) Light-Emission Voltage; c) incident; d) reflected; e) 1st - 25th wafer.

[Figure 9]



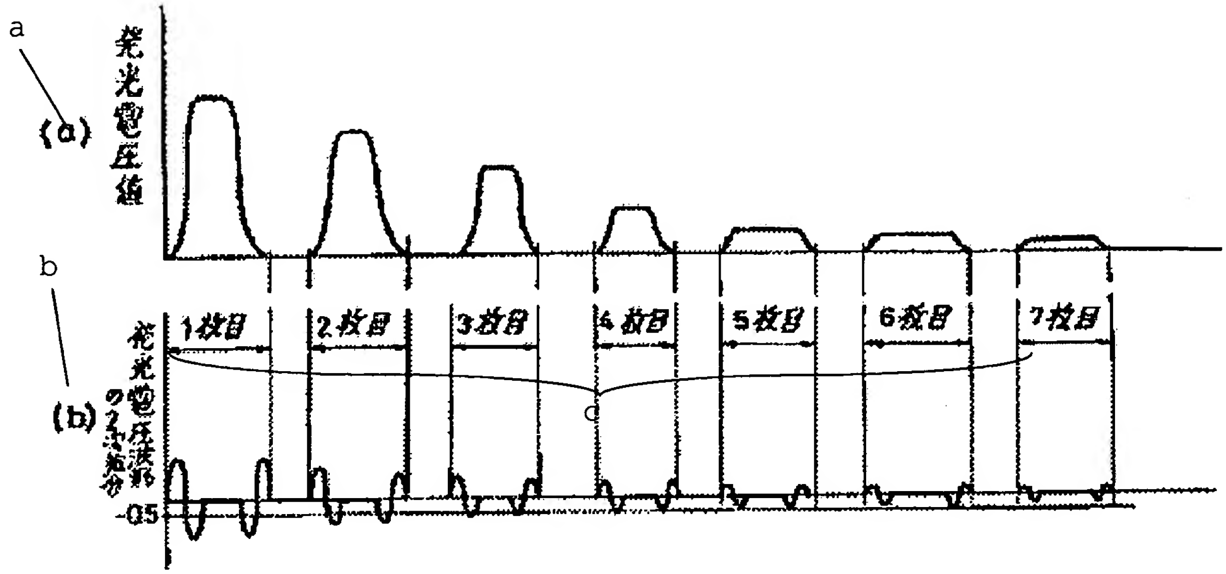
Key: 1)etching gas; 2)gas inlet tube; 3)quartz bell jar; 4)treatment chamber; 6)microwaves; 7)microwave guide; 8)coil for generating an electromagnetic field; 9)ECR plane; 10)plasma; 11)wafer; 12)reaction product; 13)optical fiber; 14)filter; 15)photomultiplier.

[Figure 10]



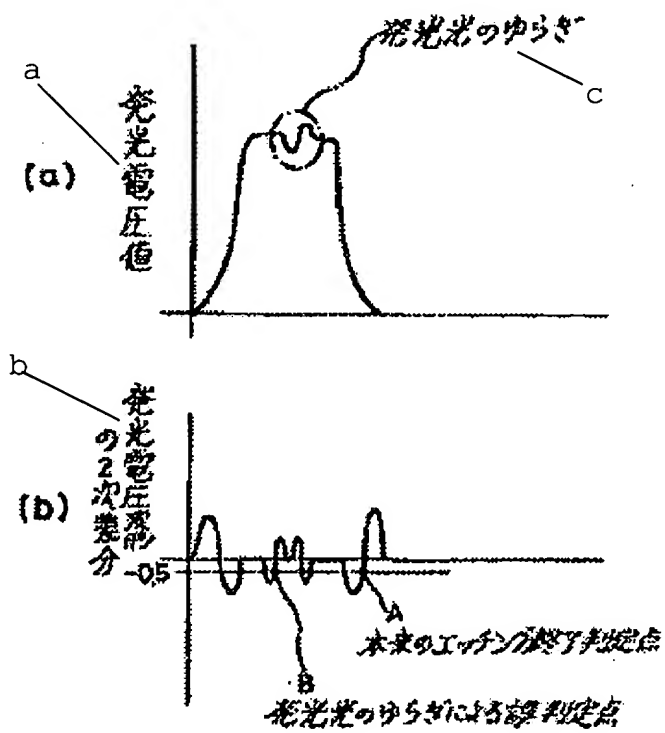
Key: a)Light-emission voltage; b)Secondary difference of light-emission voltage waveform; c)etching start; d)etching time (sec.); e)transition point from downward curve to upward curve.

[Figure 11]



Key: a) Light-emission voltage; b) Secondary difference of light-emission voltage waveform; c) 1st - 7th wafer.

[Figure 12]



Key: a) Light-emission voltage; b) Secondary difference of light-emission voltage waveform; c) Fluctuations of emitted light; A) Actual etching endpoint; B) Endpoint incorrectly detected due to fluctuations of emitted light.